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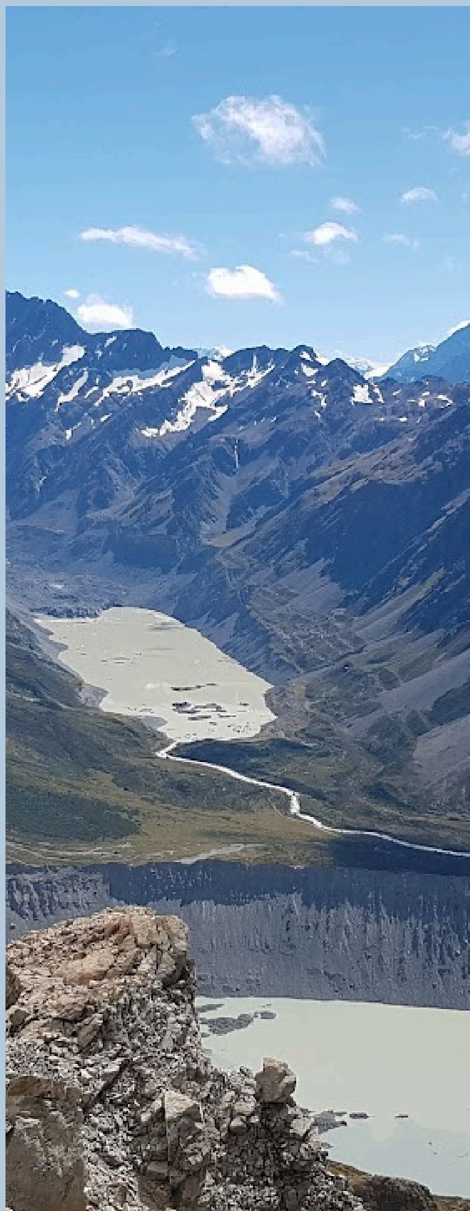


FIELDTRIP GUIDE

GLACIAL GEOMORPHOLOGY OF THE WAIMAKARIRI VALLEY

2026

manatiaki kōawa rivers GROUP

11TH IAG INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY

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Glaciation of the Waimakariri Valley

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Introduction

This fieldtrip travels from **Christchurch** to the **Cass Basin** to examine evidence of glacial (and other) processes that have created a geomorphological wonderland in the **Waimakariri Valley** (Figure 1 – all locations highlighted in bold through this field guide are shown here). The Cass area was extensively glaciated during the last (Otiran; 74-14 ka) glaciation with the local higher peaks protruding above the ice as a series of nunataks. Since the end of the ice age and the retreat of the glaciers, over-steepened slopes have been exposed, creating the ideal conditions for a variety of mass movement processes to start. At the same time, the retreat of the ice also allowed a lake to form and then rivers to reoccupy the valley floors.

Te Wai Pounamu | South Island, New Zealand was heavily glaciated during mid- to late Pleistocene ice ages. At the peak of the last ice age about 1/3 of South Island was glaciated (e.g. Shulmeister et al., 2019). The most famous glaciers are those of the West Coast (Franz Josef and Fox) and of the Mackenzie Country (Pukaki, Tekapo, Ohau) but there were large glaciers in each of the Canterbury braided valleys. In all cases, the glaciers reached the edge of the **Canterbury Plains** during the last glaciation maximum and pre-last-glaciation advances extended many kilometers on to the plains. We are going to look at the Waimakariri Valley today. The most extensive glaciation during the last glaciation maximum reached the plains at the **Waimakariri Gorge** at about 26 ka (Rother et al., 2015). The Waimakariri Gorge mouth is a long way from the roads into the mountains so we will join the **Waimakariri River** upstream of the gorge. If you want to see the Gorge, we recommend taking the TranzAlpine rail trip which does follow the gorge and is quite spectacular.

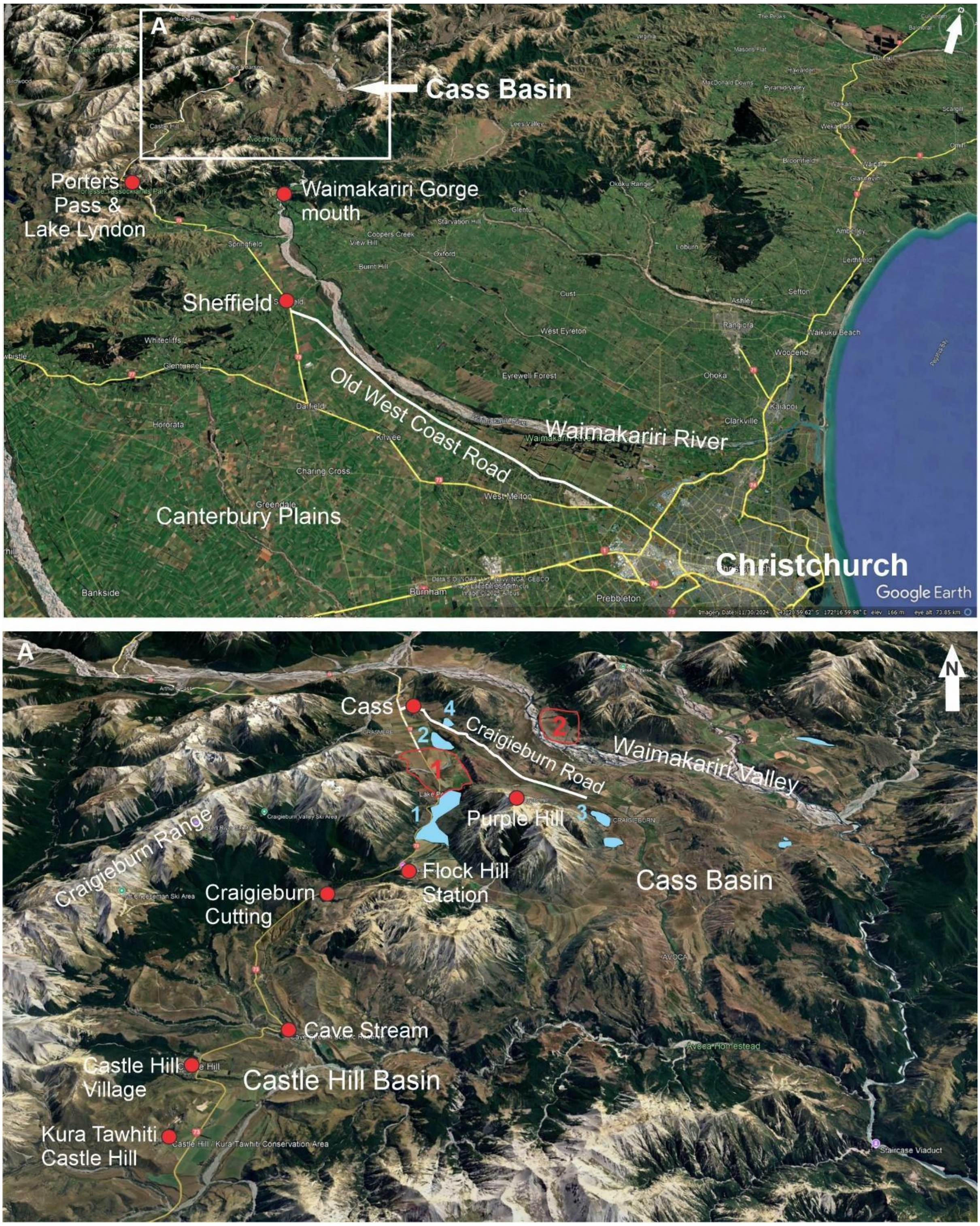

Figure 1. *Field trip route and locations of all places bolded in text. Lakes bolded in text are numbered in blue; 1) Lake Pearson, 2) Lake Grassmere, 3) Lake Hawdon, and 4) Lake Sarah. Major alluvial fans bolded in text are numbered in red; 1) Ribbonwood Fan and 2) Binser Fan. Source: Google Earth*

1.1 Canterbury Plains

We start by driving across the Canterbury Plains. Christchurch is underlain by marine and coastal sediments of Holocene age (Christchurch Formation) on its eastern side, while the west side of the city is built on gravels belonging to the Springston Formation (Figure 2). This is an interglacial gravel formation tied to the current profile/elevation of the Waimakariri River (Suggate, 1963). The Springston Formation gravels have lower slopes than the glacial age gravels of the Burnham and Windwhistle Formations, which were built during the last Otiran Ice Age.

We will travel up the **Old West Coast Road**. This road runs close to the modern Waimakariri River on a Holocene terrace surface. We will see source bordering dunes on the right hand side of the road between West Melton and Kirwee. These dunes are derived from the Waimakariri floodplains and are tied to lower terraces. They are undated but are believed to be Holocene in age.

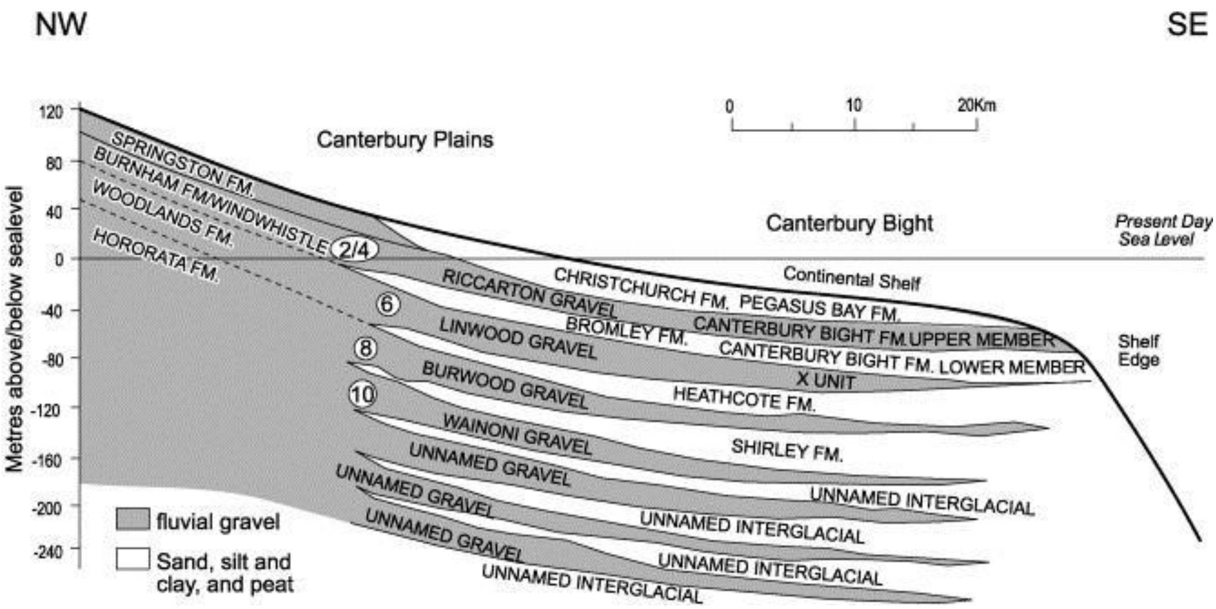

Figure 2. *Stratigraphic relationships between gravel sheets and coastal/marine sediments on the Canterbury Plains (from Brown and Weeber, 1992). Note that near Christchurch, the Christchurch formation is an estuarine and shallow marine sequence which is co-eval with the gravels of the Springston Formation further inland. Reproduced with permission from Earth Science New Zealand.*

We will have a brief stop in **Sheffield**. Canterbury Caterers is a bakery that is home to very highly regarded meat and fruit pies. Meat pies are a New Zealand specialty.

1.2 Porters Pass to Castle Hill Basin

After the stop at Springfield, we will go over **Porters Pass** where we will pass the trace of the Porters Pass Fault (Figure 3). It is believed to have last ruptured about 500-600 years ago with a likely recurrence interval of about 1500 years (Howard et al., 2004). Earthquakes on this fault are significant (estimated to be M > 7). The slip rate for the fault is estimated at 3.2-4.1 $mm.yr^{-1}$.

With the overall southern propagation of the plate boundary (due to oblique convergence), it is expected that the Porters Pass Fault will become more active over time, transferring slip from the Hope Fault (currently the dominant transform fault in the Marlborough Fault system).

Figure 3. *Trace of the Porters Pass Fault from Porter's Pass. This fault has been trenched and its recurrence interval (c. 1500 years) and magnitude of ruptures (> M 7.0) determined (authors own).*

Travelling across the pass we enter the interior basins on the eastern side of the Alps. This part of the range was either never glaciated or the glaciations were so long ago that we cannot see any obvious evidence of their existence.

The surrounding mountains are made of Torlesse rocks. These are heavily folded but only weakly metamorphosed meta-sediments of deep sea turbiditic origin. Structurally, the basins contain inliers of Cenozoic sediments including limestones and greensands in synclinal basins. While New Zealand currently lies on the plate boundary between the Australian and Pacific Plates, the period from 90 million years ago to about 22 million years ago the Zealandia continent occupied a gradually sinking passive margin setting. Repeated basin formation, associated with rifting events resulted in the formation of terrestrial swamps and fluvial deposits and of shallow marine siltstone, sandstones and limestones. Small scale basaltic volcanism is common. Up to about 5km of these shallow marine/marginal terrestrial rocks were laid down from Cretaceous to Oligocene times. The exposure of Torlesse Rocks at high elevations indicates that a minimum of 7-8 km of uplift has happened in this area during the Kaikoura Orogeny (22-0 MYA starting from the southern end of the island and propagating northward to be much more recent in this area). The hard limestone beds visible at **Kura Tawhiti | Castle Hill** and near **Cave Stream** display a complex series of folds and faults.

Lake Lyndon at the bottom of the hill beyond Porters Pass is a shallow alluvial fan constrained lake. The Lyndon valley was definitely glaciated at its western (Rakaia) end. A lake impounded in the valley by fans and the Rakaia/Wilberforce Glacier records an inter-stadial during the last Otiran ice age. This Interstadial, which occurred between ca 26,600 and 24,500 cal YR BP was remarkably mild, with summers about 1˚C cooler than modern and a maximum cooling of 3.7˚C over modern based on chironomids (Woodward and Shulmeister, 2007), or even milder based on fossil beetles (Marra et al., 2006).

As we continue towards the Castle Hill area we will observe numerous mass movement landforms. There are some excellent examples of debris flows with well developed levees (Figure 4). These erosional features start as deep gullies high on the hill side with the debris provided by the very friable Torlesse rocks. Alluvial fans are also noteworthy but the most spectacular examples of these are closer to Cass.

We pass by the limestone inlier of Castle Hill which is a well known bouldering location and then swing north towards **Castle Hill Village**. The **Craigieburn Range** is visible on the left hand side. This range has been subject to frequent rock avalanches. Turnbull and Davies (2006) proposed an interesting hypothesis on the formation of cirques. They argue that rock avalanches create source basins that would be ideal for cirque formation. Several of their key examples are from the Craigieburn Range. The best are further back in the range (e.g. Figure 5) but we will discuss the proposed process while looking at an example visible from the road.

Figure 4. *a) Debris flow fan with well developed levees just off the road near Castle Hill. Source: Google Earth. b) close up of debris fan. Incised section at front indicates reduced debris flow events in recent past. Authors' own.*

Figure 5. *Cirque like feature in the Craigieburn Range near Castle Hill village. Landslide depressions like this were highlighted as possible proto-Cirques by Turnbull and Davies (2006) (author's own).*

Approaching Cave Stream there are an impressive series of river terraces with a distinctly underfit stream (Cave Stream) in the valley (Figure 6). We will stop to examine and discuss this valley. The geological and geomorphological context is quite complex. The local limestone outlines a number of deformed folds. Karst processes have resulted in the Cave Stream entering a cave, making the Cave Stream Valley a blind Valley. Nevertheless, the underfit nature of the stream relates neither to the tectonics nor karst processes. It is because this valley used to carry glacial melt-water from the Craigieburn River during the peak of the last ice age. At that time, ice from the Waimakariri Glacier (specifically the Winding Creek Lobe) occupied the **Craigieburn Cutting** and diverted the Craigieburn River, that currently flows down the cutting, into Cave Stream. The combination of outflow from the glacier and the flow of the Craigieburn Stream created a high aggradation terrace. There is a lower intermediate terrace, still likely related to higher flows. Even the modern valley floor suggests higher than modern flows with the cave stream meandering within its current valley.

Figure 6. *The terrace sequence on Cave Stream. The two higher terraces were formed when meltwater from the Waimakariri Glacier was diverted into this stream. The river now has a limited catchment in the Craigieburn Range (authors own).*

1.3 Entering the Cass Basin

We pass by a flat surface just before going down the Craigieburn Cutting which is the outwash surface for the Waimakariri Glacier and Craigieburn Stream during glacial maximum times and down the Craigieburn Cutting. As noted before, ice abutted the cutting and filled in the valley during these times. Once onto the cutting, we are within the maximum extent of the former Waimakariri Glacier.

The original glacial mapping in this part of the Waimakariri was by Gage (1958). A CRN chronology, that resulted in reconsidering some of the older glaciations, was produced by Rother et al. (2015).
Three lobes of the Waimakariri Glacier worked their way through this area. The main road follows the 'Winding Creek' Lobe which extended through what is now **Lake Pearson** and records a series of recessional moraines in the valley on the southern side of **Purple Hill** (see also Figure 8 from Rother et al., 2015). These represent a recessional sequence c. 17 – 25 ka old.

We pass by **Flock Hill Station** at the bottom of the cutting and off to our right are the terminal moraines of the Winding Creek Lobe of the Waimakariri Glacier (Figure 7, Figure 8 C). These moraines are c. 17 ka (Rother et al., 2015) and are the equivalent of the Poulter Moraines in the main Waimakariri valley (Gage, 1958).

These represent only the final recessional phase of the last (Otiran) glaciation in this area. The valley is a deep glacial trough that was largely excavated of sediment during the more substantial advances of the last glaciation. Ice stagnation in this valley segment, created by the detachment of this lobe from the main Waimakariri Glacier when ice heights fell below the elevation of the saddle between Cass and the main Waimakariri Valley, resulted in the formation of lakes where glacial tongues melted out. These are reflected by Lake Pearson, **Lake Grassmere**, **Lake Hawdon** and others.

Because the valley floor was cleared of sediments during glacial times this section of the valley has some of the best developed alluvial fans in New Zealand. Sediment trapped in the interior catchments of local hills spilled out onto the valley floor when the glaciers melted. Lake Pearson is almost dissected by alluvial fans and it is one of the most photogenic fans around. The even larger **Ribbonwood Fan** is so large that it is not easily photographed. It partly blocks Lake Grassmere and buries much of a terminal glacial position that lies diagonally across the valley from the downstream end of Lake Grassmere to the edge of the Ribbonwood Fan on the other side of the valley. These moraines yield statistically identical ages (17-18 ka) to the inner moraines at Purple Hill.

Shortly after passing the Ribbonwood Fan we will turn into the **Cass Settlement** and travel up to the University of Canterbury field station for a comfort stop.

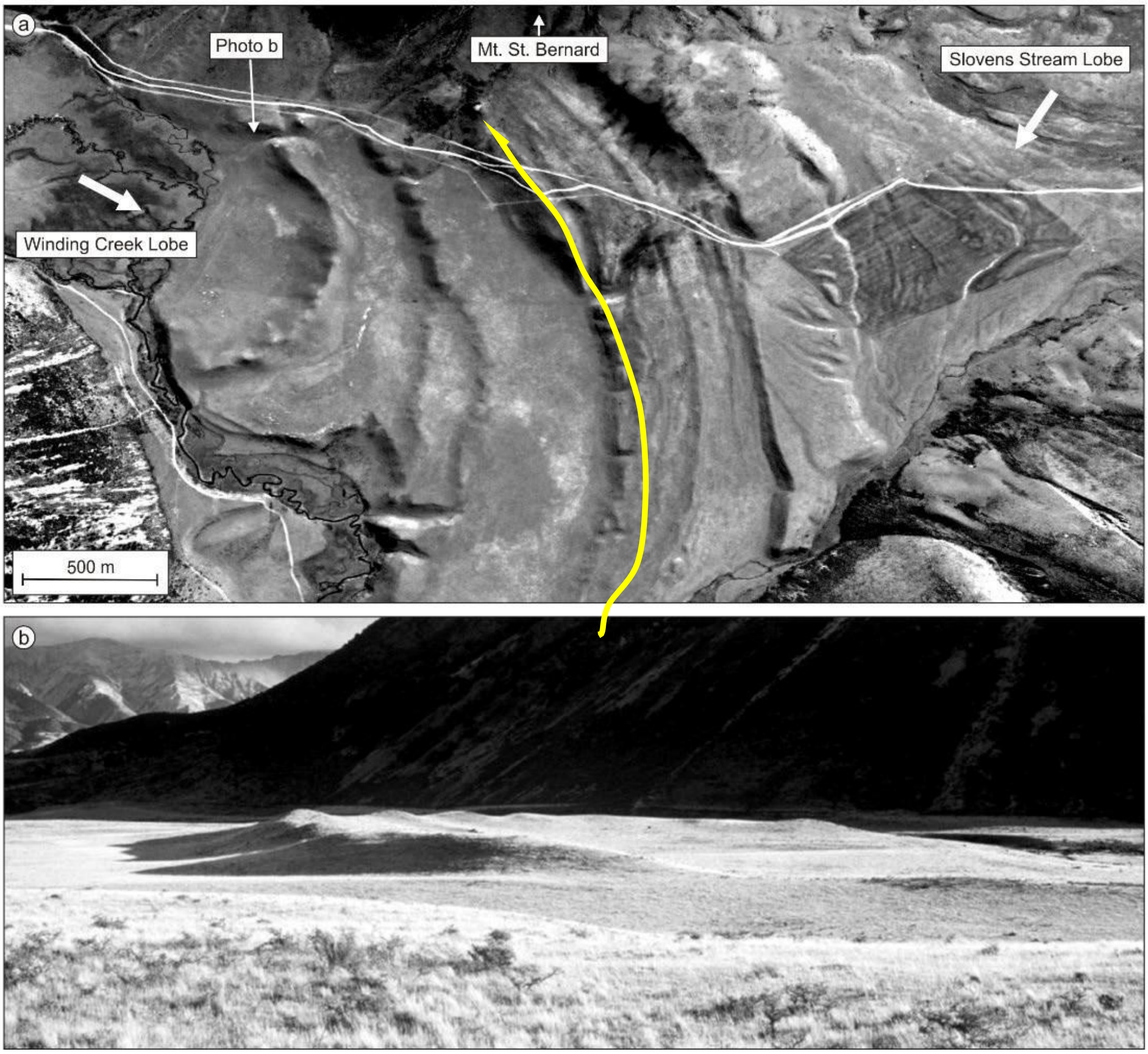

Figure 7. *Top. 17 ka moraines of the Winding Creek Lobe, these are the equivalent of the Poulter Moraines in the main valley. Bottom. Side on view of a moraine line (from Rother et al., 2015). An example loop has been highlighted in yellow in the top panel. Copyright of Elsevier – authors derivative product.*

1.4 The Waimakariri Valley

Travelling down the **Craigieburn Road** (yes there are a lot of things called Craigieburn around here) we pass by Romulus and Remus, two hills that are Rochè Moutonèes. The narrow valley we are travelling along contained another distributary lobe of the Waimakariri Glacier – the Slovens Lobe. We pass by **Lake Sarah** which is impounded by late stage ice breaking out of the main Waimakariri Valley and forming a moraine loop across this Valley (Figure 8).

We will stop at a small gravel pit which gives us a section through part of the moraine and discuss the sedimentological processes.

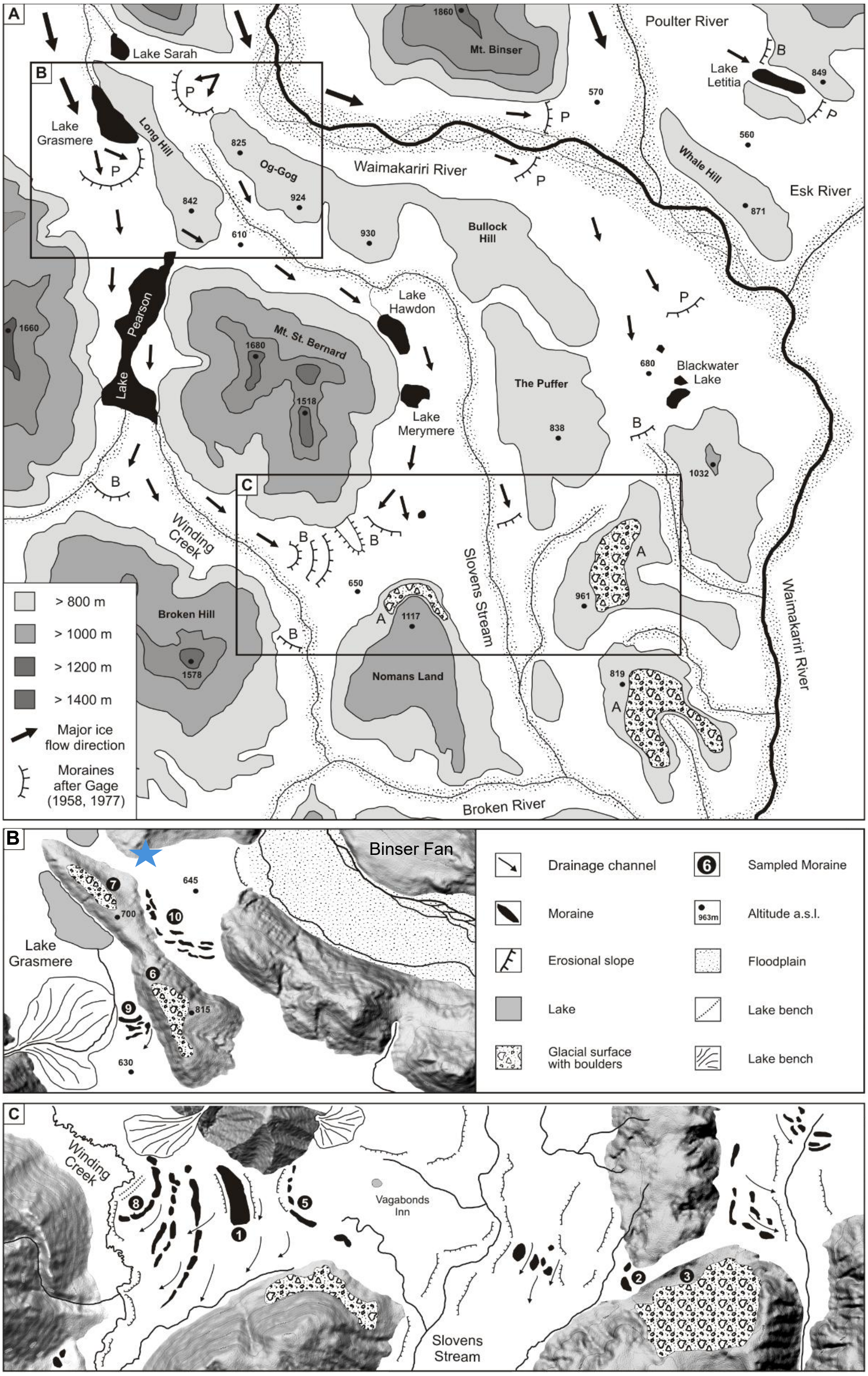

Figure 8. *Figures from Rother et al. (2015) showing ice routes and positions of moraines in the Cass/Flock Hill area. Kettlehole bog is marked as a blue star in the middle panel. Copyright of Elsevier – authors derivative product.*

We will then proceed to Kettlehole Bog (Figure 8 B) to discuss the post-glacial vegetation history of this area. Kettlehole Bog is, as its name suggests, a kettle hole in the moraine loop. Yet again this moraine dates to between 17-18 ka.

The vegetation history (as derived in Figure 9) is as follows;

Immediately after the glaciation grasses and daisies dominated in a tundra like environment. Forest invaded after about 16300 cal yr BP but tundra like conditions we re-established during the Antarctic Cold Reversal (McGlone et al., 2004). After 13,000 cal years BP a succession from shrubs, through montane podocarps to lowland podcarps occurred over a period of about 4000 years (McGlone et al., 2011). After 9000 cal yr BP southern Beech (Fuscaspora spp) invaded the area. We will discuss the relationship between vegetation type and regional climate through the deglaciation and Holocene.

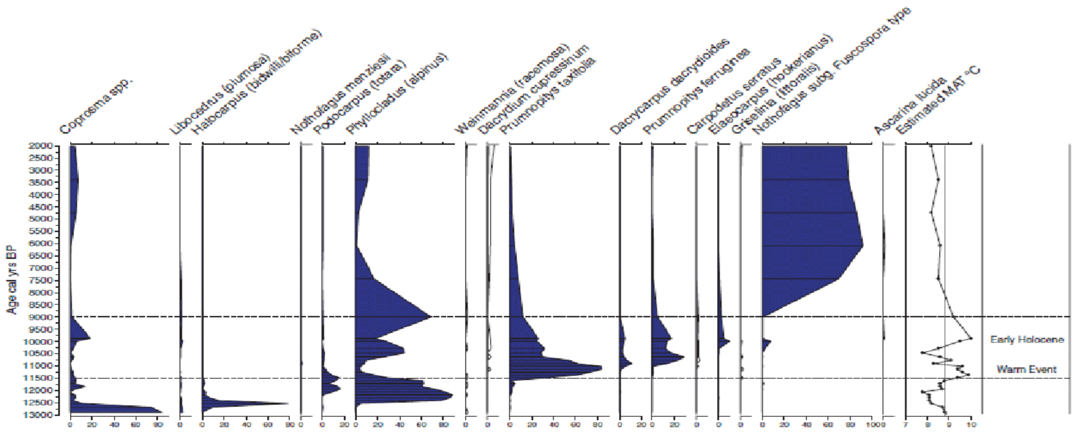

__Figure 9.__ The record of the last c.13,000 years of vegetation change from Kettlehole Bog (from McGlone et al., 2011).

Continuing down Craigieburn Road for a little over a kilometer we will stop to inspect the terminal moraines and outwash gravels of the late glacial glacier that broke into this valley. This terrace edge style terminal moraine and outwash sequence is typical of many New Zealand glaciers both during the last ice age and during advance phases in the last few decades (e.g. Shulmeister, 2017). They are very similar to the moraine and terrace sequences mapped by Soons (1963) in the Rakaia Valley. At the moraines we will discuss the nature of glaciation in New Zealand and why, at least in some of the bigger river valleys, we see such extensive outwash surfaces and such minor moraines.

From here we will walk over a low hill (there is at least one fence line to cross) and sidle our way into the main Waimakariri Valley to examine the glacial and post-glacial history visible from the hill side. There is a bit of a climb towards the top of the ridge because this will give us a better view over the valley.

The Waimakariri is a classic braided river and the braid plain is spectacular. Opposite where we are standing we can see a very large alluvial fan called the **Binser Fan** (Figure 10; Figure 8 B). Around the edges of the fan, lake beaches are incised. These lake beaches relate to 'Glacial' Lake Speight (Gage, 1958). The existence of a large lake is clear. There are a series of beaches recorded on both sides of the valley. The evidence for the lake extends north nearly to the Mt White Bridge and there is a delta tied to a high lake phase preserved there.

Figure 10. *The Binser Fan, with beaches from Lake Speight incised into its outer edge. Ice marginal drainages of the Waimakariri Glacier are visible to the right of the fan (authors own).*

This lake was identified by Gage as a proglacial lake that formed during the retreat of ice from a moraine position at the Poulter River confluence. Again, this is the 17-18 ka moraine position (Rother et al., 2015). Winkler et al. (2018) argue that the Gage model requires a dam at the confluence to last a very long period, which makes the lack of survival of dam remnants improbable. They also point to evidence for a landslide deposit that intermingles with the Poulter Moraine. More importantly, they highlight that if the lake dates to the Poulter Moraine, it implies very rapid (possibly unrealistic) development of the Binser Fan, as the fan was fully developed when the lake was present.

The valley contains evidence for both limited valley glaciation marked by terminal and lateral moraines, outwash gravels and glacial marginal drainages of a variety of styles. Truncated spurs, ice carved bedrock and the overall U shape highlight older larger glaciation. The ridges on the south side of the valley, including the one we are standing on, were over-run during MIS2/3 with a c. 24 ka age from boulders on the ridge between the Slovens and Winding Creek lobes. There is evidence for truncated spurs and glacial benches high up the sides of the higher hills indicating >500 m of ice depth in the valley at the times of the largest glaciations.

There is an asymmetry in sediment storage on the valley sides. The north side, at least away from the Binser Fan has very little sediment. The south side, which we are standing on, has a thick sediment package. On the surface there are lateral moraines and glacial benches incised by local drainage and at lower elevations by Lake Speight. There is a substantial outcrop in a gully a few hundred meters up valley and downslope of where we are standing (Figure 11). We will now examine this outcrop.

Figure 11. *Inside the sediment package on the Waimakariri Valley flank. Note the difference between grey and creamy sediments. The grey gravels are aggradation gravels associated with a glacial advance down valley. The cream sediments are a weakly stratified diamicton. They are interpreted as sub-aqueous, glacial proximal, mass flow deposit reflecting an ice margin in a lake (e.g. Evans et al., 2013) (authors own).*

The outcrop is a bit hazardous to approach so we will examine it from an adjacent ridge.

Once we have looked at the outcrop we will work our way back to the bus. There will be a stop at Springfield on the way back to Christchurch.

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